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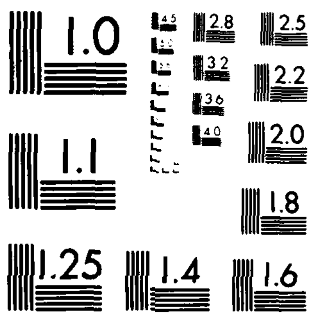

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TECHNICAL REPORT RH–84–3

TIME VARIABILITY OF DIRECTIONALITY PROPERTIES OF PULSED EB–EDL N_2 – CO_2 LASERS

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FEBRUARY 1984

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Measurements were made of the time dependence of radiation intensity in various parts of the far-field patterns of pulsed e-beam electric discharge laser (EB-EDL) N_2-CO_2 lasers. It was found that the relative intensity of the early-time gain-switch spike as compared to the later-time main pulse was different in different portions of the far-field pattern when the resonator alignment was of fully decentered type. (author)

I. INTRODUCTION

An important practical feature of lasers is the high directionality of the output beam. For cw lasers, and also for many pulsed lasers, directionality is very good, being essentially limited only by diffraction. However, significant reductions in directionality can occur for some pulsed lasers.

One cause of reduced directionality is incomplete "transverse mode formation." This occurs when a substantial fraction of the total pulse power is emitted in a time shorter than that which is required for development of a well-formed transverse mode. This phenomena is presumably independent of the detailed properties of the pumping scheme, and has been observed with various gain media. Observation of this phenomenon in an electron beam initiated, electric-discharge (EB-EDL) sustained CO_2 laser operated without an admixture of N_2 was recently reported[1]. A report on the phenomenon observed in an EB-alone pumped excimer laser will soon be available[2]. Some of the work on transverse mode formation has been limited to observations of the spatial distribution (often a burn pattern in a suitable material) in the focal plane integrated over the total duration of the output. The present work includes both burn patterns and measurements of the time dependence of the radiation intensity at various points in the focal plane.

The observations reported herein indicate a reduction of directionality under conditions such that "transverse mode formation" does not seem to be the cause. The reported phenomena presumably do depend on the nature of the pumping scheme.

The present work employed two EB-EDL lasers which contain both N_2 and CO_2 in the gain medium and produce a double output pulse for each laser shot, namely a gain spike followed by the main pulse. The spike has significant effects in some applications in target coupling. These effects would be modified if the far-field spatial distribution of radiation in the gain spike is significantly different from that of radiation in the main pulse. Such different directionality properties of the gain spike and the main pulse have been observed and are being reported herein.

II. EXPERIMENTS

Observations reported here include two distinct sets of experiments with different lasers of the same general type but with quite different magnifications. The arrangement for the first set of experiments is indicated in Figure 1. The EB-EDL laser[3] used a 1:2:3 gas mixture of N_2:CO_2:He at a pressure of one atmosphere. The nominal energy output was some 200 Joules within a pulse length of about 3.5 μ sec. The gain region was 100 cm in length, with a cathode to anode separation of 11 cm and a width of 10 cm.

The unstable resonator cavity was formed by a pair of mirrors placed so that at the confocal spacing of 2.892 meters, the magnification is 1.32. A mirror spacing of 3.374 meters was used in order to produce an output beam which focused on an experimental position located 136 meters downbeam. Observations were made with the resonator in each of two principal arrangements, namely centered alignment and fully decentered alignment; the latter is

illustrated in Figure 1. Important differences in results were obtained with the two types of alignment. The time-dependent directionality properties which were observed occurred only for the decentered alignment configurations; further discussions will be limited to such configurations.

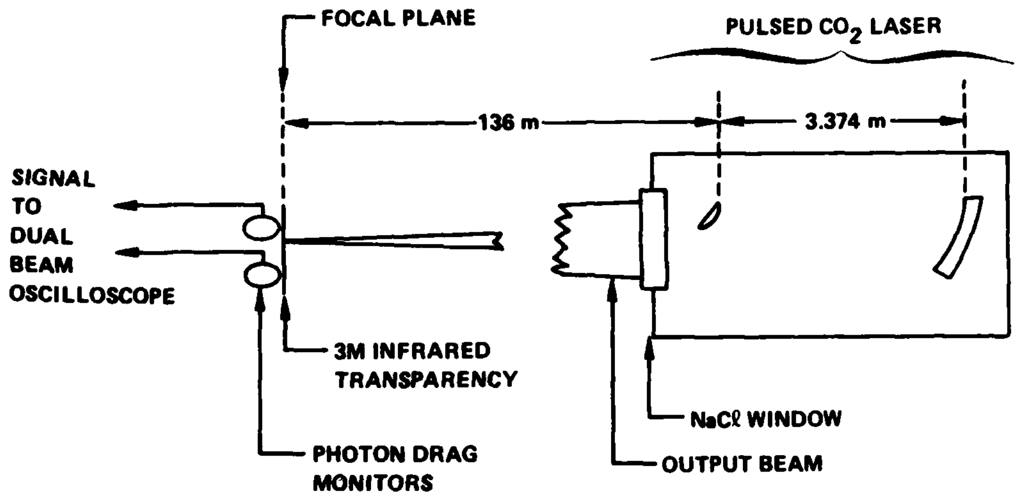


Figure 1. Experimental test configuration for observations of directionality properties of pulsed laser (using unstable resonator with decentered alignment.)

For some of the laser shots, the temporal behavior of the near field intensity was recorded using photon drag detectors; an example is shown in Figure 2. There is no appreciable difference between the two traces regarding the relative heights of the gain-switch spike and the later main pulse. This contrasts with observations made in the far-field as discussed below.

The principal far-field measurements which were made for each laser shot were: (a) a conventional burn pattern on a 3M (Minnesota Mining and Manufacturing) transparency showing the spatial distribution of the time-integrated far-field intensity and (b) the time history of the radiation intensity measured at two points in the focal plane. The latter measurements were obtained using photon drag detectors (rise time less than 1 nsec) located behind holes cut into a 3M transparency which was placed at the general position of the expected far-field pattern prior to pulsing the laser. The response of the two detectors was recorded on a dual beam oscilloscope. After the shot, the precise location of the two detectors relative to the time-integrated far-field pattern could be readily noted from inspection of the burn pattern on the 3M material.

Figure 3 shows the focal plane burn pattern obtained with a typical shot. It also shows the positions of the holes behind which were placed photon drag detectors. One of the holes falls at a secondary maximum in the pattern, while the other falls at a point of very low fluency. The time history of the radiation intensity at these positions is shown in Figure 4; the relative intensity of the main pulse as compared to the gain-switch spike is greatly different at the two detector positions. This general feature was rather common in the set of measurements which were made using this laser (with a decentered resonator). Figure 5 is a near-field burn pattern from the decentered resonator.

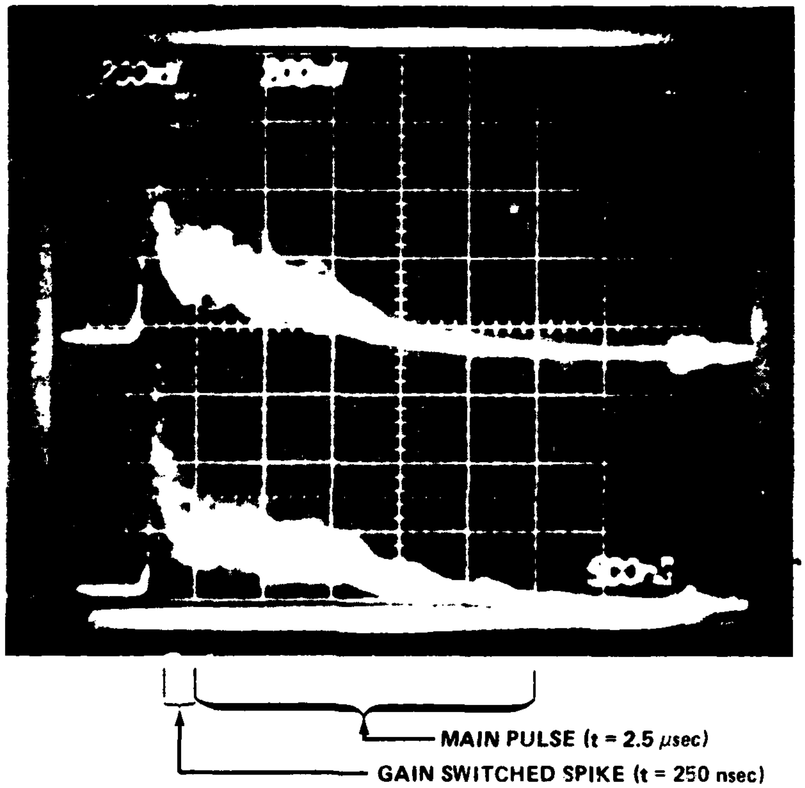


Figure 2. Temporal shape of the laser pulse in the near field (detectors were placed near the anode and cathode side of the beam). The slight horizontal offset is a misalignment with the oscilloscope.

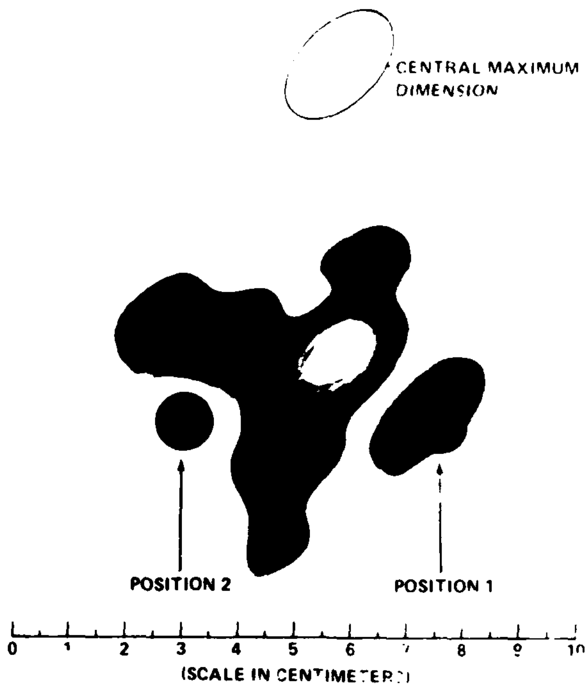
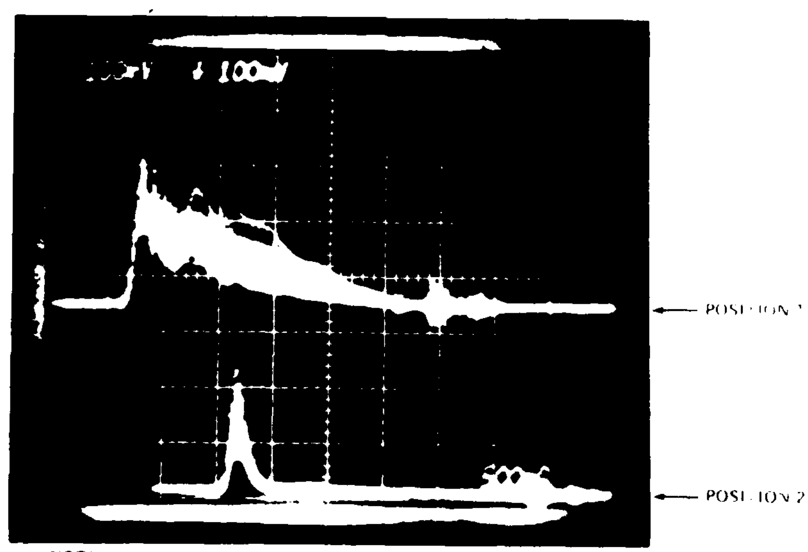


Figure 3. Far-field observations. Focal plane burn pattern (detectors were placed behind holes at positions 1 and 2).



NOTE: EACH DIVISION ON THE GRAPH REPRESENTS 500 nsec

Figure 4. Far-field observations. Temporal shapes of the focal-plane intensities at positions 1 and 2 as recorded with photon drag detectors (the bottom trace has been deliberately displaced horizontally approximately 900 nsec or 1.8 divisions on the graph.)

Figure 5. Near-field burn pattern taken 50 cm from CO_2 laser. (Feed-back mirror support partially block the beam on top and bottom.)

Similar measurements were made with a second CO_2 laser[4], which is similar in general characteristics to the laser described above but is larger and has a more intense output. It was operated with a nominal resonator magnification of about 2.23. The above noted directionality properties were also observed in experiments carried out with the second laser with decentered alignment. An example of these properties is shown in Figures 6, 7, and 8, which shows temporal traces of the near-field and 3 far-field positions at 225 meters, respectively.

The observed differential directionality of radiation emitted during the gain-switch spike and the main pulse portions of the output is consistent with various possible interpretations. One of these is a "mode-formation" interpretation in the sense described above. This possibility was investigated in a separate series of experiments, results of which argue against that interpretation. Another possible interpretation is slewing of the output beam through an angle of the order of half a diffraction angle during the period of the overall output pulse. This might occur due to laser-medium gradients arising from behavior of the electron beam which pre-ionizes the gas[5]. A further series of investigations is being undertaken in an effort to clarify the cause of the observed phenomena.

III. CONCLUSIONS

It has been found that significantly different directionality properties are associated with the radiation emitted during the time of the gain-switch spike and of the later main pulse for a rather common type of electrically pulsed N_2-CO_2 laser when operated with an unstable resonator with fully decentered alignment. This undesired time variability of directionality can be avoided by restricting the resonator alignment to be of centered type. Imposition of that restriction, however, eliminates advantages of the more compact far-field distributions which can be achieved with decentered alignment[6].

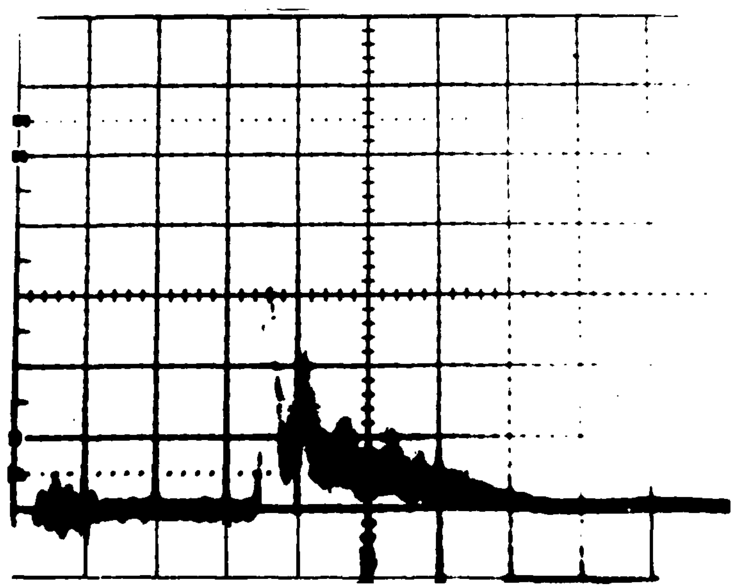


Figure 6. Simultaneous temporal traces of a pulsed CO_2 laser. Near-field intensity.

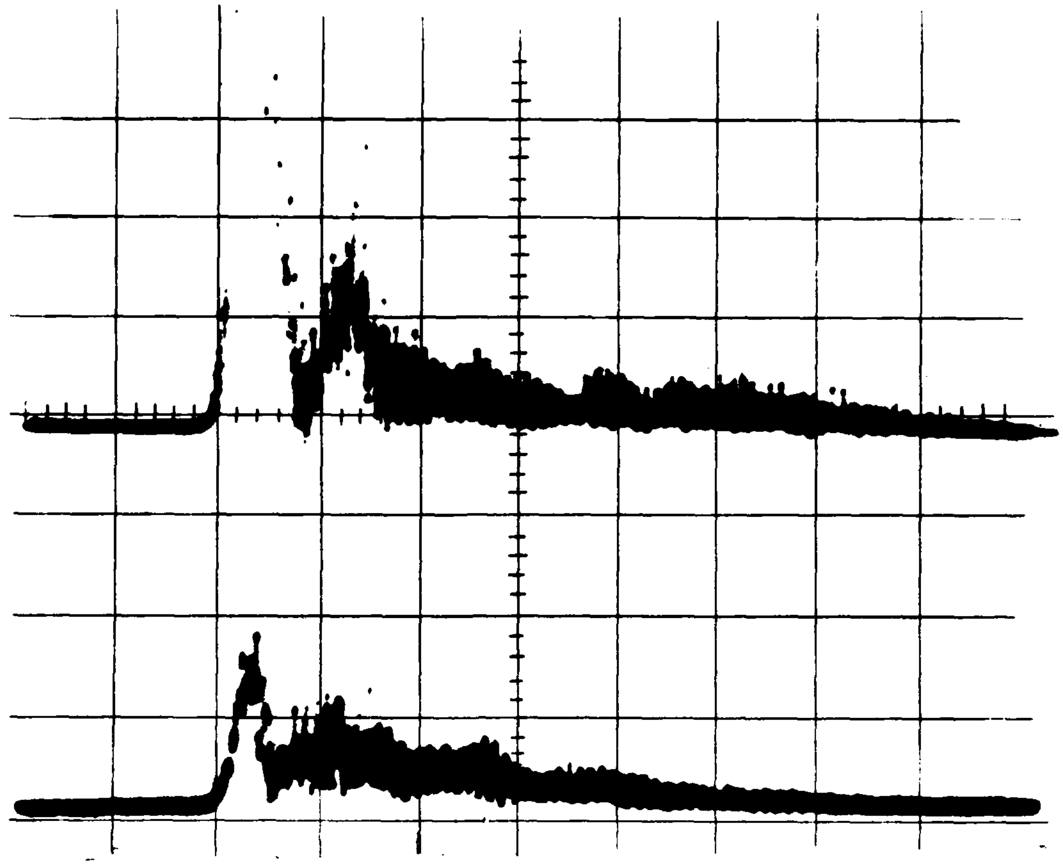


Figure 7. Simultaneous temporal traces of a pulsed CO_2 laser. Far-field intensity at 225 meters.

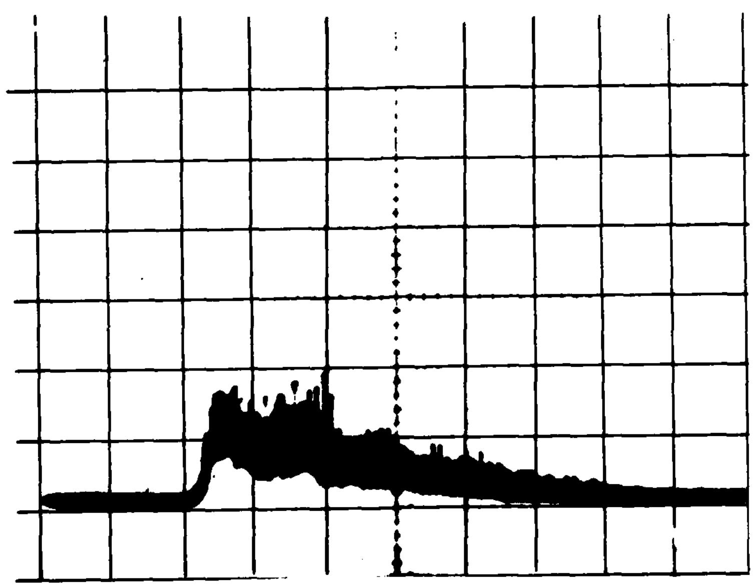


Figure 8. Simultaneous temporal traces of a pulsed CO_2 laser. Far-field intensity at 225 meters.

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